2016

Development Of Micro Channel Heat Exchanger For Residential Air-Conditioners

Gaku Hayase
SAMSUNG ELECTRONICS CO. LTD, Korea, Republic of (South Korea), gaku.hayase@samsung.com

Development of Micro Channel Heat Exchanger for Residential Air-Conditioners

Gaku HAYASE[1]*

[1]Advanced R&D Team, Digital Appliances Division, SAMSUNG ELECTRONICS CO. LTD,
129, Samsung-road, Yeongtong-gu, Suwon-city, Gyeonggi-do, Korea
Phone: +82-31-8062-5855, E-mail: gaku.hayase@samsung.com

ABSTRACT

In this paper, 4 types of micro channel heat exchanger which applied residential air-conditioner is shown. We know that micro channel heat exchanger is more effective for a performance enhancement than cross fin and tube heat exchanger in residential air-conditioner. And micro channel heat exchanger helps to reduce refrigerant quantities in residential air-conditioner systems. Micro channel heat exchanger is used with the air-conditioner for almost all vehicles, but it has not been used in residential air-conditioner yet. In Samsung Electronics, we applied micro channel condenser to the outdoor unit of the air-conditioner (cooling only model) since 2006. And we developed the micro channel evaporator to the indoor unit of the air-conditioner in 2011, which modified the heat exchanger for the car. Also in order to solve the frost and de-frost problem in heat pump outdoor unit, we developed a new micro channel condenser which changed the corrugate fin to the flat fin in 2012. To apply to a heat pump indoor unit, we developed the new type micro channel evaporator in 2013, which constructed micro channel tube perpendicularly and header horizontally with flat fin. Finally we finished the development of 4 types of micro channel heat exchanger which is applicable to all of residential air conditioner products.

1. INTRODUCTION

The electric power reduction request of air conditioner is rising every year. And the performance improvement competition of element parts comprising air conditioner is becoming very severe. The improvement of not only the existing rating efficiency (EER: Energy Efficiency Ratio, COP: Coefficients of Performance) but also SEER (Seasonal EER), SCOP (Seasonal COP) considered the real use environment is required. And the high performance of the impact is greater in the improved efficiency of the heat exchanger with a compressor can be regarded as a very important factor in the development of air conditioning proceeds as product.
In response to the needs, high performance development of heat exchanger in recent years is thinner and smaller tube of the indoor heat exchanger to the partial load improvement and the heat transfer area -up of the outdoor heat exchanger to the frost / defrost operation performance is the mainstream.

2. ALL-ALUMINIUM PARARELL FLOW TYPE HEAT EXCHANGER FOR THE COOLING ONLY AIR CONDITIONING SYSTEM

As s heat exchanger of air conditioner, the fin & tube type heat exchanger consisting of the copper tube and aluminum fin has been widely used. Recently, the development of replacement material to replace a copper tube according to the rise in copper price since 2006 is being required.
In case of the fin & tube type heat exchanger in auto mobile air conditioner, “small-size” and “light-weight” were realized by changing it into the parallel flow type heat exchanger (1988). This heat exchanger can increase heat transfer capacity considerably by using micro-channel flat tubes which can enhance the refrigerant-side heat transfer coefficient and reduce the air-side flow resistance and contact thermal resistance between flat tube and aluminum fins through the NOCOLOK brazing technology. Consequently, it results in remarkable manufacturing cost savings.

After the understanding of this heat exchanger technology, we applied this technology into our residential air conditioning application through making and testing many prototypes for our applications. Finally, our own parallel flow type heat exchanger was developed and under mass production now. This success is considered a kind of

innovative invention or product in our residential air conditioning application fields due to its highly heat transfer performance and cost down effects (Fig. 1).

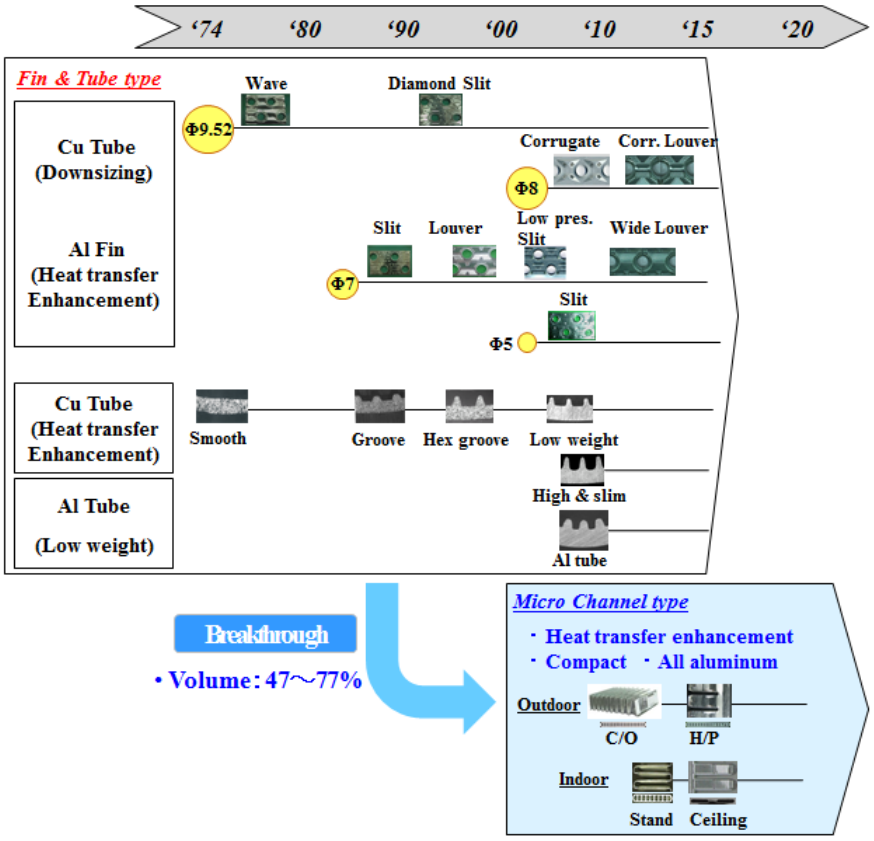


Figure 1: Trend of High Performance Heat Exchanger in Samsung

The auto mobile air conditioner is operated for only cooling mode. It has two parallel flow heat exchangers, such as evaporator and condenser. In case of an evaporator, a pair of headers is horizontally placed with many micro-channel flat tubes vertically installed while a condenser is vice versa. Considering the conception and condition of two parallel flow heat exchangers, we can apply them into our residential air conditioner easily without big change of heat exchanger specifications regardless of the differences in between auto mobile and residential air conditioners, such as, refrigerant, refrigerant flow rate, air volume flow rate.

Our exclusive parallel flow heat exchangers for the stand type air conditioner are illustrated in Fig. 2. Conventional parallel flow heat exchangers in auto mobile industry have 2 rows and several up & down flow pass through micro-channel flat tubes with the width of 15mm over and the hydraulic diameter of 1.5 ~ 2.5 mm.

One of our exclusive parallel flow heat exchanger, as an evaporator, has 2 rows and up and down flow pass configuration as shown in Fig. 2(Left). The hydraulic diameter of micro-channel flat tube is about 1.0 mm and is carefully designed in order to meet the standards and regulations in refrigerant side pressure drop and burst pressure for residential air conditioners. The width of our micro-channel flat tube is about 12mm per a row and also is carefully designed by considering the air side heat transfer characteristics and pressure drop and noise level under the half of air velocity frequently used in auto mobile applications. Finally, our evaporator showed equal performance with previous fin & tube heat exchanger, although it has half size of fin & tube heat exchanger (Fig. 4(a)). The other is the parallel flow condenser. The hydraulic diameter of the micro-channel flat tube is about 0.8 mm and the width is 16 mm. These specifications are same with conventional auto mobile application. However, refrigerant flow pass is redesigned and optimized to meet our design guidelines. It is noted that our manufacturing process and equipment setup can be easily established in the short term by referring the technology in auto mobile industry. Finally, our condenser showed equal performance with previous fin & tube heat exchanger (7Ø , 2 rows), even though it has 40% size of fin & with heat exchanger. (Fig. 4(b))

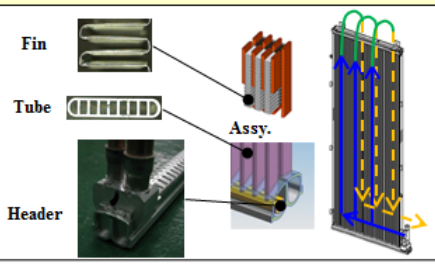
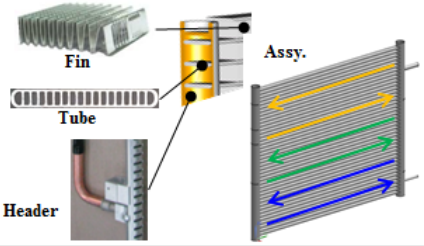
	For cooling only model	
	Indoor unit	Out door unit
Appearance		
Configuration	Tube (Vertical), Header (Horizontal)	Tube (Horizontal), Header (Vertical)
Multi channel tube	12mm (8mm) × 2 row	16mm(10mm) × 1 low
Characteristic	Condensate drain available Most suitable for floor type products Condensation performance is insufficiency	Maximization of condensation performance Condensate drain impossible Frost/defrost performance is the worst

Figure 2: All aluminum parallel flow type heat exchangers for cooling only air conditioner

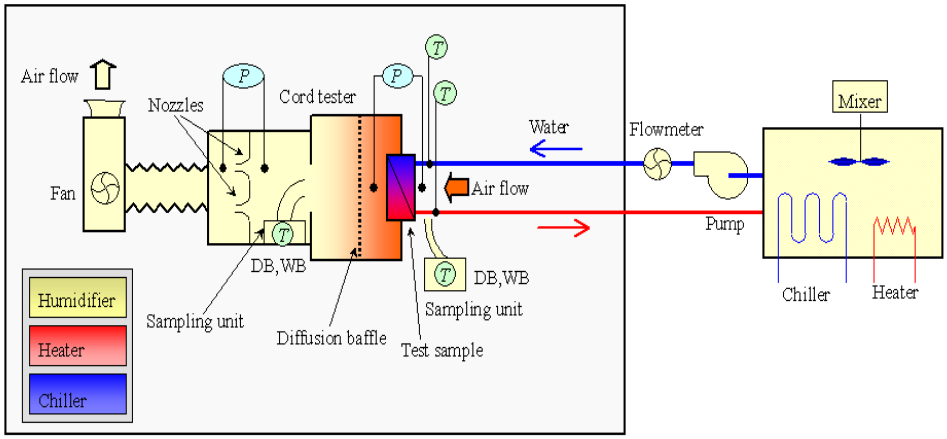
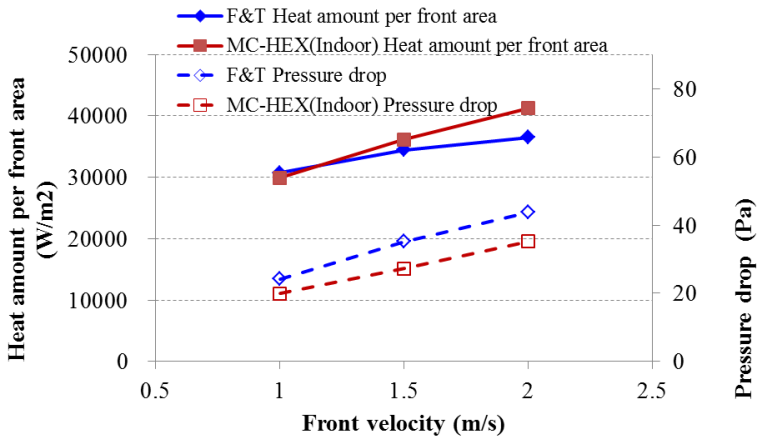
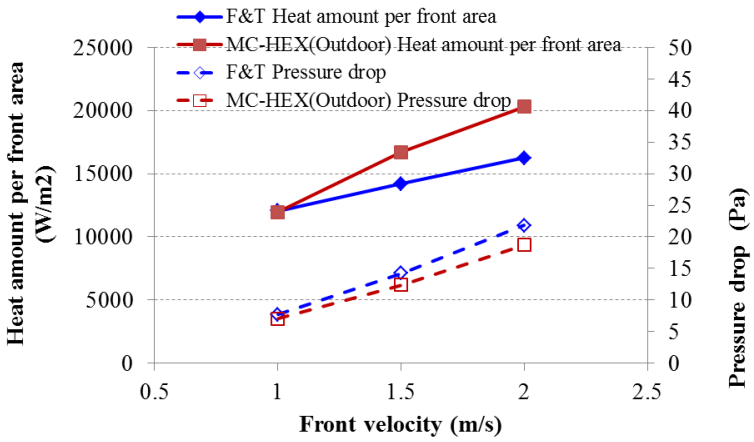


Figure 3: Schematic diagram of heat exchanger capacity test



(a) About parallel flow evaporator



(b) About parallel flow condenser

Figure 4: Comparison of the performance between fin & tube and MC-HEX

In general, all refrigerant pipes are copper tube. A new piping method was developed for connecting aluminum heat exchanger with refrigerant pipe during NOCOLOK brazing process in order to avoid hetero-metal junction in assembling air conditioner. Specially designed STS part is inserted between in/outlet of aluminum heat exchanger and copper tubes. Through this new piping method, corrosion resistance of joint and productivity are accomplished simultaneously.

3. ALL-ALUMINUM PARALLEL FLOW TYPE HEAT EXCHANGER FOR HEAT PUMP SYSTEM

As it described previously, in case of cooling only system, considerable performance improvement and "small-size" and "light-weight" effect could be realized with heat transfer technology of auto mobile industry. However, there is a fatal defect that these heat exchangers cannot be directly applied to heat pump system.

For an example, in case of the parallel flow heat exchanger with vertical flow direction for indoor unit, heat transfer performance could decrease, because part of refrigerant flow in reverse due to the gravity effect during condensation. For the parallel flow heat exchanger with horizontal flow direction for outdoor unit, heat transfer performance could fall down because condensate water is not easily drained during evaporation. In addition to, there is another problem that frost characteristic is not good. Moreover, the parallel flow heat exchanger with vertical flow direction is appropriate for the stand type air conditioner but it is not applicable for other type air conditioner like wall mounted air conditioner due to its configuration and orientation. Therefore, a new concept for solving this fatal defect should be needed in order to apply all aluminum parallel flow heat exchangers to all kinds of air conditioners.

Fig. 5 illustrates the outline of all aluminum parallel flow heat exchanger for heat pump air conditioning system. Both indoor and outdoor units have vertical header and horizontal micro-channel flat tubes. One of the biggest features is that specially designed fins are employed like one used in fin & tube heat exchanger. Hence, micro-channel flat tube can be installed vertically, which gives easy assembly and further performance than horizontal type. First, for the parallel flow heat exchanger for indoor unit, the width of flat tube is 9.5mm (per 1 row) and the hydraulic diameter is about 0.9 mm. Fig. 6 shows equal capacity although it has 60% size of previous fin & tube heat exchanger (7Φ, 3 rows). Air flows from the side of micro-channel flat tube inserted to the edge of the fin where the condensate is collected and drained. Good drainage performance are realized and obtained for the special installation angle of heat exchanger for the indoor unit of air conditioner.

Secondly, for the parallel flow heat exchanger outdoor unit, the width of flat tube is 20 mm and the hydraulic diameter is about 1.1 mm. Fig. 7 shows equal capacity although it has 75% size of previous fin & tube heat exchanger (7Φ, 2 rows). Air flows from the opposite side of flat tube inserted to the front of the fin. The length between the edge of the fin and the end of flat tube is so sufficient that the frost cannot easily grow up (Fig. 8). Consequently, frost characteristics are considerably improved by twice than previous fin & tube heat exchanger. Also, two phase flow distribution characteristics are improved during evaporation by installing several baffles with different refrigerant flow area along the header, which controls refrigerant flow speed.

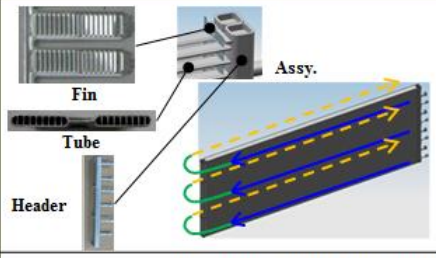
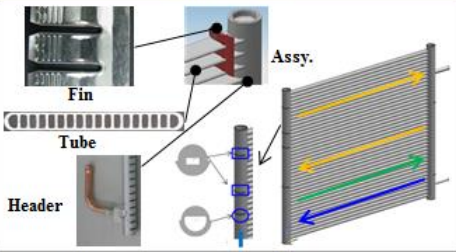
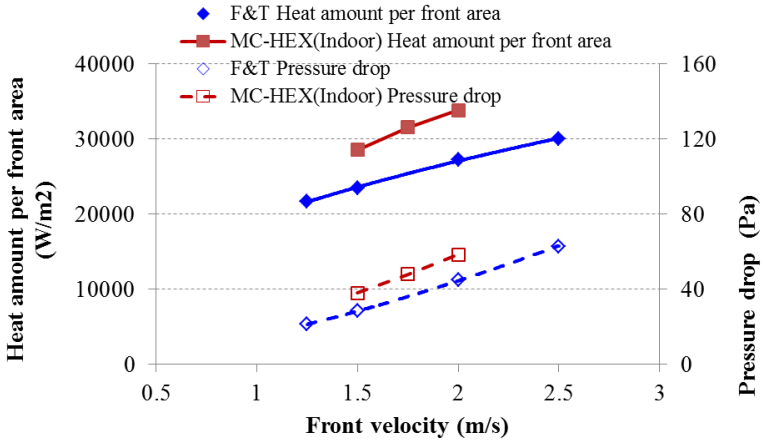
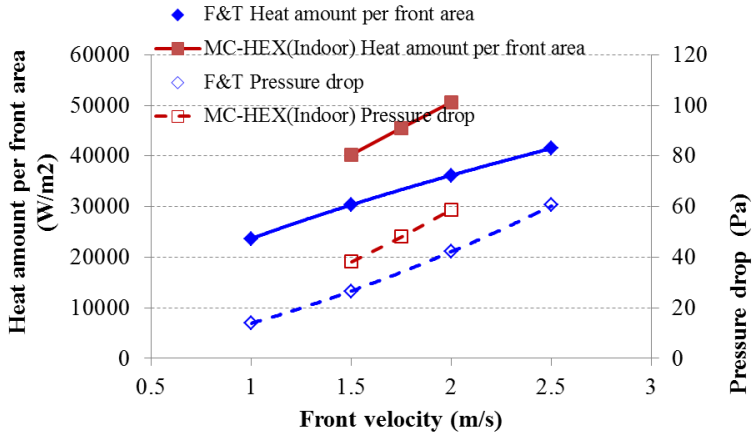
	For heat pump model	
	Indoor unit	Out door unit
Appearance		
Configuration	Tube (Horizontal), Header (Vertical), Insertion type fin (Vertical)	
Multi channel tube	9.5mm×2 raw	20mm×1 raw
Characteristic	Condensate drain available (Slant installing available)	Condensate drain available Frost/defrost performance is good

Figure 5: All aluminum parallel flow heat exchanger of air conditioner for heat pump

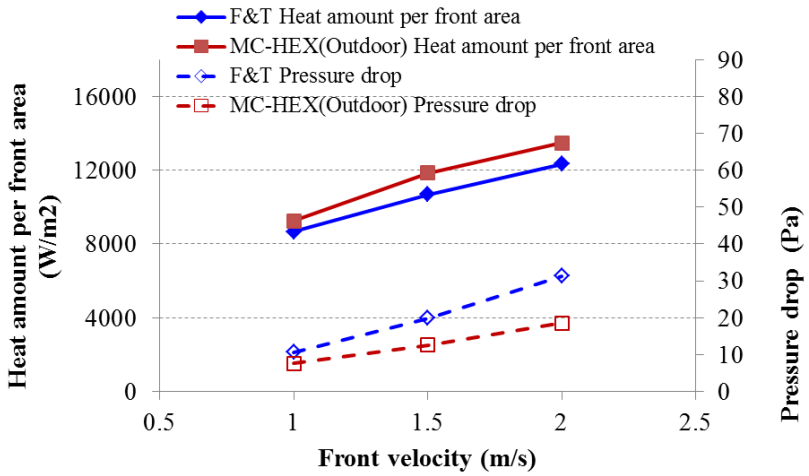


(a) About parallel flow heat exchanger for indoor unit (Evaporation condition)

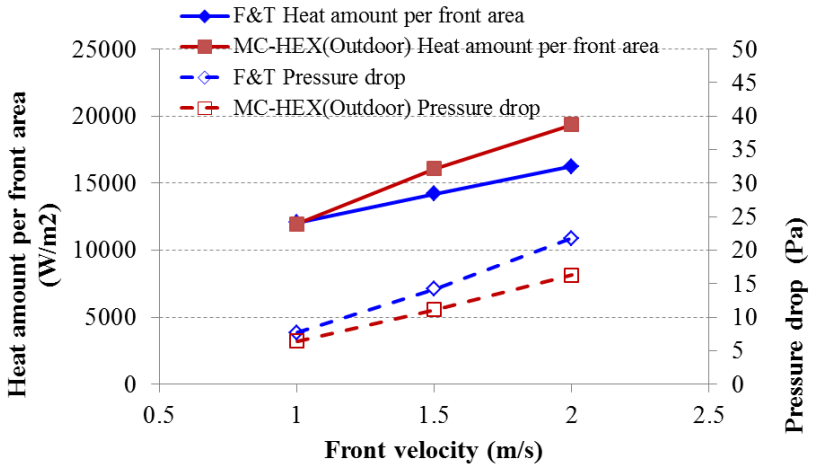


(b) About parallel flow heat exchanger for indoor unit (Condensation condition)

Figure 6: Comparison of the performance between fin & tube and MC-HEX



(a) About parallel flow heat exchanger for outdoor unit (Evaporation condition)



(b) About parallel flow heat exchanger for outdoor unit (Condensation condition)
Figure 7: Comparison of the performance between fin & tube and MC-HEX

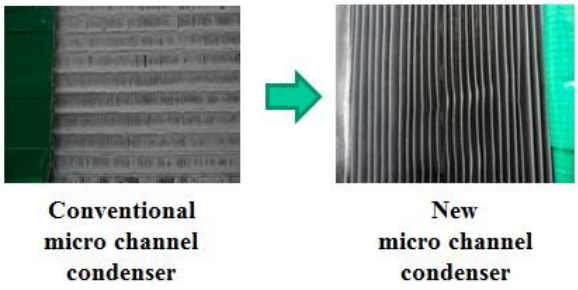


Figure 8: State of the frost after 30 minutes (air side velocity 1.5m/s, temp. 2/1℃)

4. IMPROVEMENT OF MATERIALS FOR PARALLEL FLOW TYPE HEAT EXCHANGER

4.1 Development of new post coating system

Fin & tube heat exchanger consists of aluminum fin and copper tube. Aluminum fin is made of aluminum foil with a

pre-coated film on its surface in order to enhance the hydrophilic property or corrosion resistance. Therefore, it is called "pre-coat" method. Aluminum heat exchanger uses "post-coat" method now that aluminum heat exchanger should be brazed in a furnace with higher temperature heat source. This post-coat method consists of three stages. First, acid or alkali cleaning and water washing is performed so that the flux used in NOCOLOK brazing can be easily removed. Second, chemical conversion treatment is carried out to ensure the coating paint sticking property of aluminum surface and corrosion resistance working properly. Finally, hydrophilic coating gets to be done. Generally, 8 to 10 process is needed for dipping method.

For the purpose of process reduction, flux amount is minimized by applying flux on the surface of micro-channel flat tube before assembling parallel flow heat exchanger. Therefore, cleaning process can be reduced from 3 to 1. Also, film adhesion performance is improved by putting organic crosslinking agent into hydrophilic paint. Moreover, corrosion resistance is improved by putting Cr3+ inhibitor so that the film is formed. Finally, dipping adopted coating system was developed with 3 simple processes and has been applied for all aluminum parallel flow heat exchanger for indoor and outdoor units (Fig. 9).

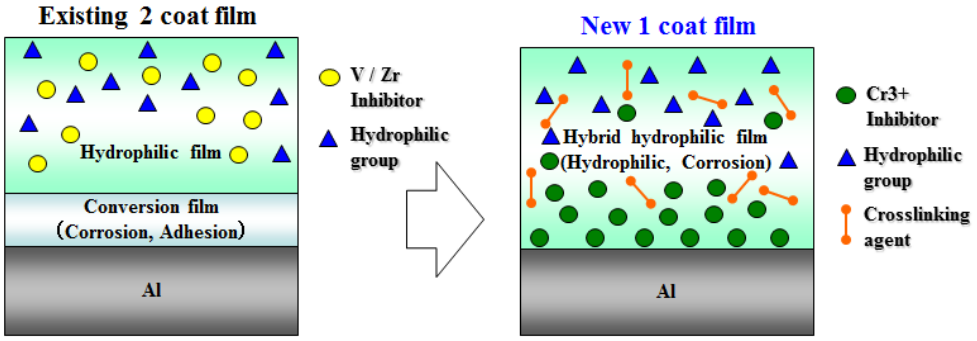


Figure 9: Development of new post coating system

4.2 The corrosion resistance reliability enhancement of the all-aluminum parallel flow type

As described above, development of all aluminum parallel flow heat exchangers covering various types of air conditioners including heat pump system have been nearly completed. Also it is considered that full-scale replacement for previous fin & tube heat exchanger are ready to start in point of mass production.

In the meantime, there is a deep distrust in the market point of view on the aluminum corrosion. Therefore, it is needed to prove and ensure the reliability of aluminum corrosion.

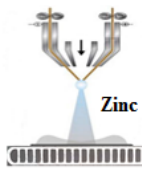
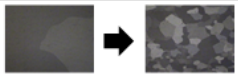
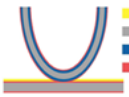
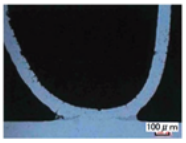
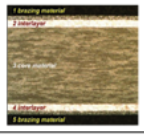
	1990~	2000~	2010~	Future
Appearance	 Zinc spray Zn: 10~20 (g/㎡) → 5~10 (g/㎡)	 Prevention coarsening of tube (High Mn, Low Fe, Low Cu)  Zn Flux, Aluminium base alloy, Clad alloy (filler metal), Aluminium oxide layer Zn / Sil / Li Flux	 Potential design: Ecorr(Tube) > Ecorr(Fin)	 Folded Tube  Multi layer clad material
Characteristic	Sacrificed corrosion with Zn layer	Corrosion resistance reinforce o f tube material Introduction functional flux	Increasing tube corrosion resistance with potential design (Fin sacrificed)	Increasing tube corrosion resistance with folded tube using rolling materials
ISSUE	Performance reduced by Fin-Tube de-bonding	Increasing of tube cost	Performance reduced by fin corrosion	Need roll forming machine

Figure 10: The corrosion resistance technology trend of the aluminum parallel flow heat exchanger

In the begin of development of all aluminum parallel flow heat exchanger (1990~), anti-corrosion technology has been obtained by victimizing and corroding the zinc diffusion layer spread on the surface of flat tube in the auto mobile industry. Recently, this technology proceeds to how to delay the tube side corrosion and how to reinforce the

corrosion resistance of tube itself by victimizing and corroding fin using the design concept of corrosion potential between two different materials as shown in Fig. 10. It is expected that the technology using folded tube is next anti-corrosion solution. However, since there is no confidence in the management of brazing quality and no capability to setup facility and equipment required for making folded tube, a few years will be needed until full scale introduction.

5. CONCLUSIONS

For the purpose of replacing all aluminum parallel flow heat exchangers as a heat exchanger for all kinds of air conditioner, the improvement of anti-corrosion technology and degree of flexibility for product application should be done. In addition, refrigerant distribution characteristics should be improved.

In case of fin & tube heat exchanger, it is possible to cover different capacity range of air conditioner under the condition of using same chassis by arbitrarily changing the number of rows, passes, and fin pitch even under the same frontal area of heat exchanger. However, in case of all aluminum parallel flow heat exchanger, it is not easy to cover different capacity range due to lack of flexibility for design resulting from the limit of manufacturing method and assembling process. Therefore, module design and consideration of hybrid system between two heat exchangers according to the capacity of product are needed.

On the other hand, refrigerant flow mal-distribution is one of the main problem deteriorate heat transfer rate of air conditioner. It is noted that present mechanism for flow distribution is just suitable for the standard operating conditions. Hence, both dynamic and static devices for flow distribution control mechanism which is not affected by the refrigerant flow change in the inverter system should be required. And proper treatments for the Low GWP refrigerant system have to be arranged.

Even though many researches and developments for the fin & tube heat exchanger of air conditioner have been conducted in several years, such as, thinner copper tube, hybrid tube system with different diameters, foaming metal, and finless heat exchangers, it is clearly assured that all aluminum parallel flow heat exchanger is most favored alternative for the fin & tube heat exchanger lasting several decades and next generation technology itself.

REFERENCES

Hayase, Choi, Seo, Cho, 2011, Proceedings of the 2011 JSRAE Annual Conference, Tokyo, pp407-410
Hayase, Choi, Cho, 2011, Proceedings of the 2011 JSRAE Annual Conference, Tokyo, pp403-406
Hosono, Okinotani, Sakano, 2011, Proceedings of the 2011 JSRAE Annual Conference, Tokyo, pp391-392
Hayase, Choi, Kim, 2012, Proceedings of the 2012 JSRAE Annual Conference, Sapporo, pp11-12
Kamata, Kim, Fujino, 2012, Proceedings of the 2012 JSRAE Annual Conference, Sapporo, pp37-40
Hayase, 2012, Proceedings of the 2012 JSRAE Annual Conference, Sapporo, pp41-42
Kotani, Nakano, Suzuki, Tajima, 2013, Proceedings of the 2013 JSRAE Annual Conference, Tokyo, pp131-134
Hayase, Seo, Cho, 2013, Proceedings of the 2013 JSRAE Annual Conference, Tokyo, pp357-358
Ishibashi, Matsuda, Okazaki, 2014, Proceedings of the 2014 SHASE & JSRAE Conference, Tokyo, pp177-180
Wang, 2015, 4th International Congress and Exhibition on Aluminum Heat Exchanger Technologies, Düsseldorf